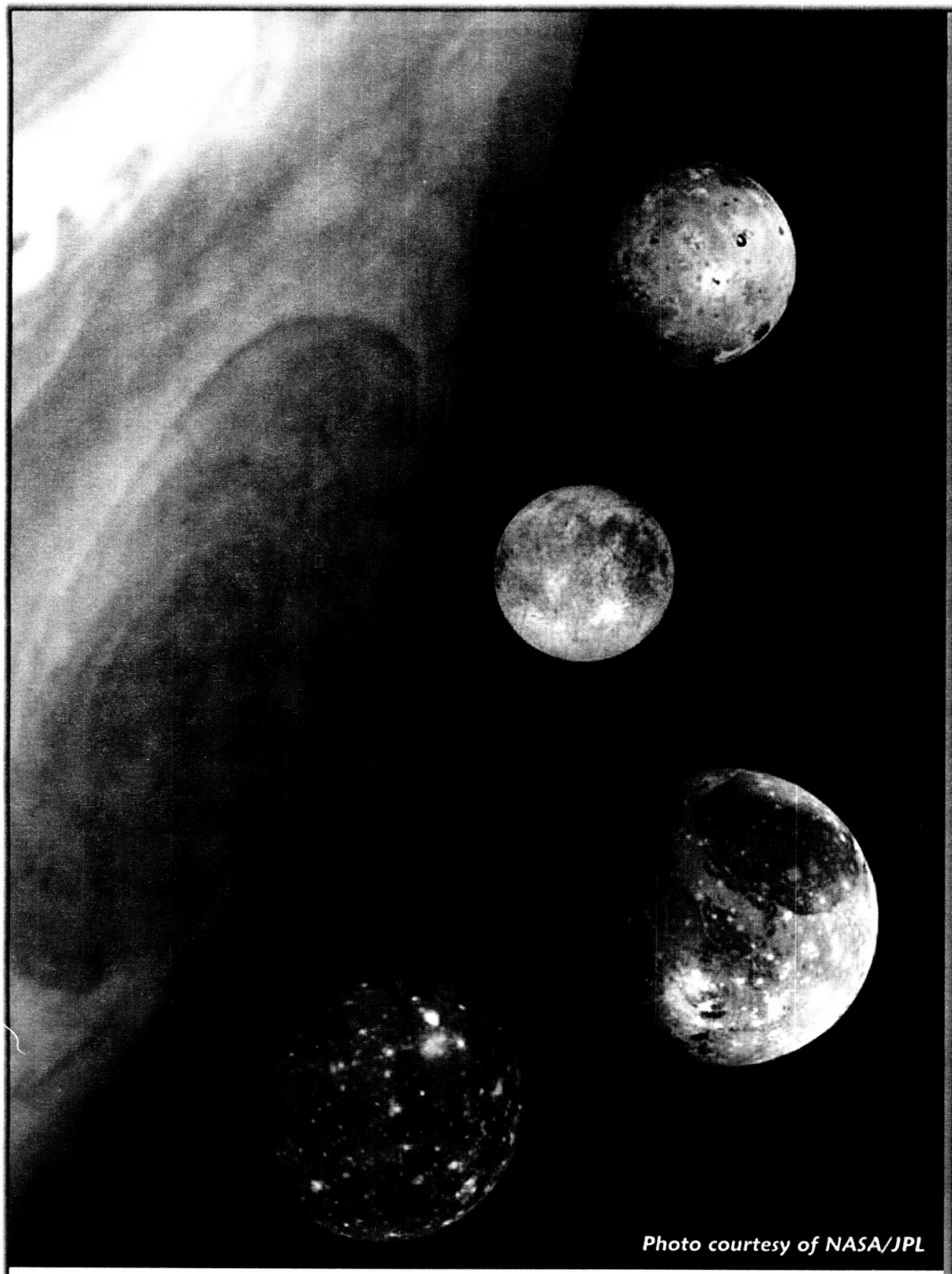


Photo courtesy of NASA/JPL

Please read the important notice about future issues on page 10.

Lunar and Planetary Information BULLETIN

Lunar and Planetary Institute — Universities Space Research Association

Fall 2003
Issue 95

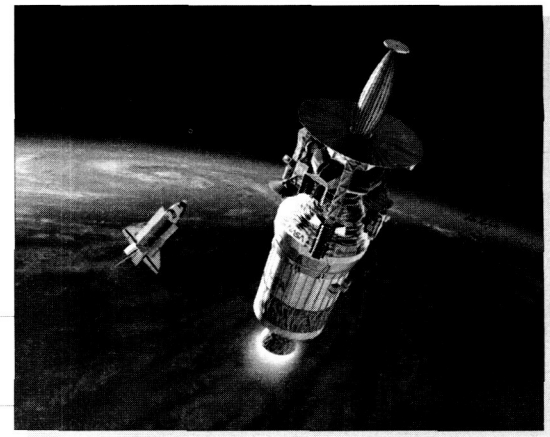
JUPITER AT THE CROSSROADS

— Paul M. Schenk, Editor

On September 21, 2003, a complex but aging man-made machine called Galileo will slam into Jupiter's turbulent atmosphere and be reduced to its basic molecular components. Behind that dry analysis lies a tale of human aspiration, struggle, and ultimate triumph. The Galileo project — conceived in 1977 to orbit and study the Jupiter system, redesigned at least three times, rescheduled four times, crippled by a major communications failure, and dosed with enough radiation to kill a human in only a few minutes — has succeeded in revealing the amazing planet Jupiter and its four planet-sized moons in unprecedented detail. As the mission draws to a close, NASA and the science teams studying the largest planet have already begun looking forward to the next step in our exploration of the Jupiter system.

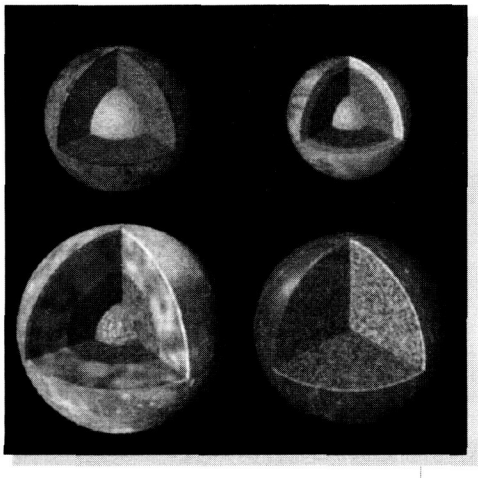
Little was known about Jupiter and its large Galilean moons Io, Europa, Ganymede, and Callisto prior to Voyager, which streaked by in 1979. The two Voyagers showed a turbulent planet and four alien moons with distinctly different and complex geologic histories, including one, Io, with intense ongoing volcanic activity. Analysis of tidal forces and evidence for sliding of crustal blocks in the frustratingly poor images of Europa suggested that some of Europa's icy crust could be liquid. However, Voyager's scientific instruments, designed in the 1960s, were primitive by today's standards, and resolutions were no better than 500 meters.

Galileo, conceived and designed before Voyager was launched, included the first charge-coupled device (CCD) imaging system and high-resolution spectral mapping instruments selected for a planetary mission. Even these instruments are two decades old, however, and are limited in their capabilities. Galileo's problems began even before launch. After several postponements and redesigns imposed on it by a nascent shuttle program, including a final redesign after the Challenger disaster, Galileo was launched in 1989 on a detour toward the inner solar system where it received a gravitational boost toward Jupiter, its main target. While in flight, the craft's parasol-like communications antenna would not open. The expected data return from Jupiter was reduced enormously (imagine a fire hose reduced to a soda straw). Overnight, our spacecraft capabilities had returned to the days of 1965, when Mariner 4 had sufficient downlink to return a total of only 22 images of Mars during its historic first flyby. Fortunately, Galileo had an onboard tape recorder and several months between satellite encounters to downlink recorded images and data.

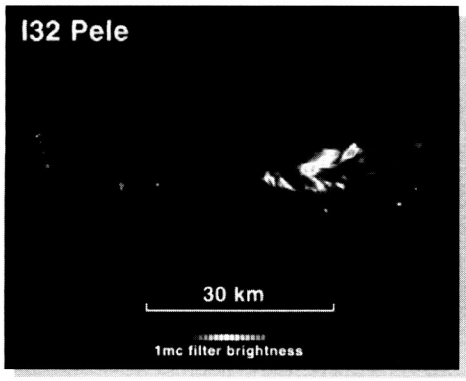


Galileo's tour of Jupiter began in 1989 with a shuttle launch. Unfortunately,the large antenna, shown here folded for launch, never properly deployed, reducing the amount of data transmitted to Earth. Photo courtesy of NASA/JPL.

In the end, Galileo was not able to achieve one of its primary goals, to provide global morphologic, compositional, and topographic mapping coverage over most of the surfaces of the four Galilean moons. As we have seen with NASA's spectacularly successful Mars missions, global mapping of this type is essential to understanding the global history and formation of geologic features on planetary bodies. A choice had to be made, and what Galileo could do best was limited very-high-resolution imaging of pre-selected targets, designed to answer key questions raised by Voyager. This was accomplished through a series of very close passes to these moons, at one point passing within 140 kilometers (86 miles) of Callisto. In this goal, the mission succeeded to grand results, revealing unexpected features at high resolution, including the complex geologic deformation of Europa and the desiccated surface of Callisto. As expected, the greatest discoveries were at Europa, where Galileo revealed a surface covered with spots, domes, cracks, and disrupted regions, all suggestive of an active geology and a thin crust. Galileo also provided the first routine monitoring of Io's prodigious volcanism, including amazing nighttime views



Galileo provided our first information on the nature of the interiors of the Galilean satellites (top row: Io and Europa, bottom row: Ganymede and Callisto). Only Callisto appears to be homogenous, without a central iron or rocky core. Europa and Ganymede have thick outer layers of water ice. Photo courtesy of NASA/JPL.

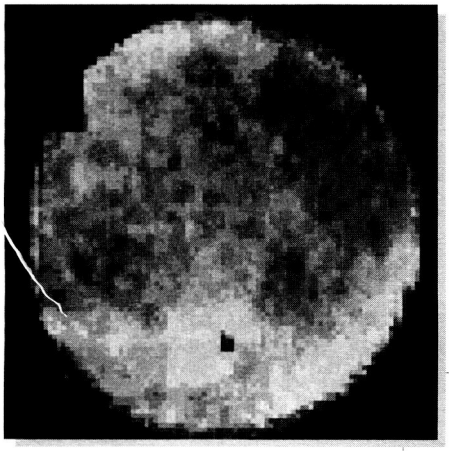


of glowing hot lavas. In the end, Galileo achieved 24 successful encounters with Jupiter's moons during its 35-orbit tour between 1996 and 2002. Solar conjunctions and radiation-induced spacecraft and instrument anomalies prevented data acquisition during 11 encounters.

Galileo's cameras were sensitive to infrared wavelengths. Io's hot lavas glow in the dark in this view of the Pele volcanic lava lake. Photo courtesy of NASA/JPL.

Galileo's other instruments provided some very surprising results as well. Perhaps the most amazing of these is evidence from the magnetic field fluctuations for oceans of liquid water, perhaps salty, deep within all three of the large icy moons, Europa, Ganymede, and Callisto. Of these Europa is the most interesting because tidal deformation of the surface keeps it warm enough so that the ice shell covering the ocean may be between only a few and 20 kilometers (12.5 miles) thick. This is very thin geologically and leaves open the possibility that organic material and perhaps even biological agents may exist in these cold dark waters. Indeed, colliding with Jupiter is designed to eliminate any possibility of an unwanted impact of the spacecraft on Europa.

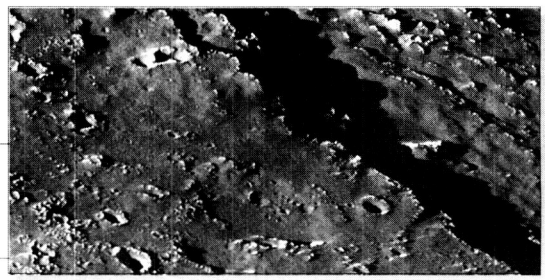
A key Galileo discovery was the pitted, freckled, ridged, and disrupted surface of icy Europa. These features are indicative of a warm interior but may also signal the presence of a liquid water ocean beneath the ice. Do any critters live in this ocean? No one is sure, yet. Photo courtesy of NASA/JPL.



Although we knew the outer layers of Europa, Ganymede, and Callisto are mostly water ice, the identity of the minor components was unknown before Galileo. The Near Infrared Mapping Spectrometer (NIMS) had the job of identifying these mystery components. Dark materials on Ganymede and Callisto are probably hydroxylated/hydrated minerals, possibly brought in by meteorites. Some local areas could be greater than 50% non-ice dark materials, at least down to a few hundred meters depth. Ozone, diatomic oxygen, and carbon dioxide, as well as several very simple organic molecules (such as CN and CH), have also been tentatively identified on the surface, and these may be related to modification of surface ices by impact or by sunlight and radiation damage.

NIMS compositional map of Ganymede, showing the distribution of hydrated minerals (dark) and water ice (bright). Although they are very low in resolution, maps such as these allow us to see the relative abundances of ices and non-ice materials. Photo courtesy of the U.S. Geological Survey.

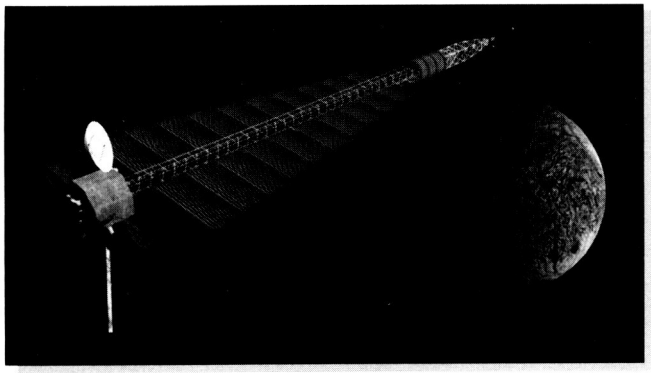
On Europa, reddish material was found to be either hydrated salts or sulfuric acid. Salts could be derived from Europa's subsurface ocean. What we do not yet know is how such salts could get to the surface of Europa. Key to future exploration strategies is the thickness of Europa's ice shell. Can we get through the shell and explore the ocean directly or do geologic processes within the shell, such as convection, bring bits of the ocean to the surface directly? Clearly these surfaces have complex compositions related to how they formed and to interactions of the surface with the interior and the space environment. Mapping compositional abundances and distributions in detail will require a return to Jupiter.



High-resolution view of the surface of Callisto. The dark smooth areas may be completely non-ice material a few hundred meters thick, formed from the sublimation or evaporation of water ice, leaving a thick deposit of dark non-ice material behind. Photo courtesy of NASA/JPL.

JUPITER AT THE CROSSROADS *(continued)*

The great diversity of this solar system in miniature, headlined by the discoveries at Europa, has placed Jupiter and its moons at the top of NASA's science and exploration objectives, second only to Mars and the New Horizons mission to Pluto! Europa in particular is important to our understanding of the basic question of whether habitats for life exist on other worlds. NASA is currently evaluating options for future missions to exploit Galileo's discoveries. Now under serious evaluation is a nuclear-powered spacecraft to orbit the icy moons of Jupiter in the next decade (the Jupiter Icy Moons Orbiter, or JIMO) and map their surfaces in great detail. Scientists from across the nation convened at the Lunar and Planetary Institute in June of this year to debate and discuss the science goals such a mission might address and how these measurements might be accomplished. Such a mission would be both exciting and potentially one of the most rewarding missions of exploration ever attempted. A final report is due to be delivered to NASA by the end of the year, but a preliminary report from the June meeting is already on line at *http://www.lpi.usra.edu/meetings/jimo2003/JIMOSummary.pdf.*



Is this the face of Jupiter's future? NASA is currently studying the possibility of sending a nuclear-powered spacecraft like this one to Jupiter during the next decade. Image courtesy of NASA/JPL.

A JIMO-style mission as conceived certainly faces daunting technical and financial challenges. These challenges include an untried and potentially costly and politically uncertain nuclear propulsion system. The severe radiation environment and long mission duration (possible more than 10 years) will also require unusually robust hardware. Landed instrument packages for one or more satellites are under consideration.

The final costs of a JIMO-style project are not likely to be small, but the gains to be made could well justify them. Galileo gave us amazing windows into these strange worlds, but we are left without global maps of geology, topography, or composition. Europa was a priority target for Galileo, but only 11% of the surface was viewed at better than 1 kilometer/pixel resolution, and less than 0.1% at better than 10-meter resolution. As the meter-resolution images taken by the Mars Orbiter Camera (MOC) have shown us, many geologic features and processes on the planets are apparent only on the local scale. The lack of global maps and meter-scale images frustrates our ability to understand what these bodies are made of, and to understand the processes shaping these surfaces over time. In particular, we do not understand the nature of Europa's putative ocean, or how thick the icy crust covering it is. Indeed, the existence of the ocean, though considered likely, has not yet been confirmed. If we are to understand how this ocean came into being and what secrets it contains, we must first understand all the Galilean satellites and why they are so similar and yet so different from each other. Sending an advanced spacecraft back to Jupiter to survey and explore in detail this planet and its family of moons is the next step to achieving this goal.

Participants of the Jupiter Icy Moons Orbiter Forum met in plenary and breakout topical sessions to discuss science objectives for a mission to explore the largest planet in our solar system.

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SPOTLIGHT ON EDUCATION

THE OSS SUPPORT NETWORK FOR OUTREACH

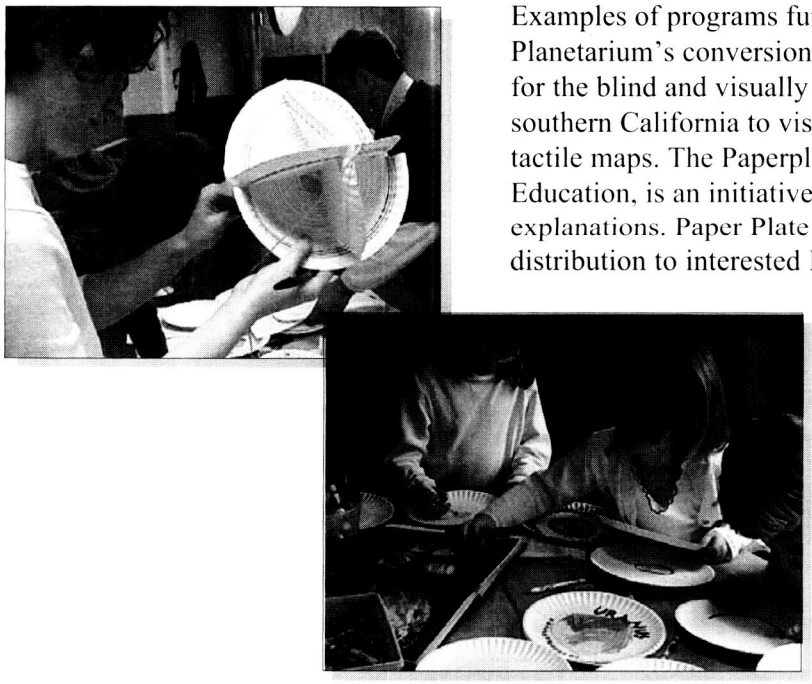
Recognizing the need to heighten investment in Education and Public Outreach (E/PO), the Broker/Facilitator network supports NASA's Office of Space Science (OSS) in its central mission to inspire the next generation of space scientists. The OSS support network is a nationwide infrastructure composed of brokers, facilitators, and educational forums that are equipped to promote E/PO activities. One of the goals of this group is to aid space science investigators in identifying and developing high-quality, high-impact E/PO programs. The network aims to help create a stronger scientific and technical workforce through partnerships between science and educational communities, as well as arrange appropriate alliances between those communities. For more information on NASA's OSS and related E/PO opportunities, please visit *http://spacescience.nasa.gov/education/index.htm.*

NASA/EPO PROGRAMS

PLATO GRANTS FOR PLANETARIUMS

DePaul University, in an initiative with NASA's Office of Space Science, offers Planetarium Learning and Teaching Opportunity (PLATO) grants. PLATO grants partner astronomy educators with the planetarium community in an effort to create space science educational projects that can be shared with others. The grants support planetarium-based projects that enhance the public's appreciation and understanding of astronomy.

Fifteen grants of up to $1000 are awarded annually to Great Lakes Planetarium Association (GLPA) members and persons affiliated with GLPA member institutions. To maximize impact of the grants, recipients provide a project evaluation and a description or model of the successful astronomy education project. These materials are available for use by other planetariums. Favorable consideration is given to replicable projects and projects that engage under-represented and underserved populations. For more detailed information regarding the application process, visit *http://analyzer.depaul.edu/NASABroker/GLPA/.*



Examples of programs funded in 2002 include Edinboro University Planetarium's conversion of a tactile full-sky chart into a tactile planisphere for the blind and visually impaired. This activity allows blind students from southern California to visualize the solar system and stars with the use of tactile maps. The Paperplate Astronomy Project, designed by Paper Plate Education, is an initiative to reduce complex notions to simple paper plate explanations. Paper Plate Education created an instructional video for distribution to interested E/PO institutions (ideas for the educational activities can be found at *http://analyzer.depaul.edu/paperplate/*). PLATO funding also supported Planetarium Space Science Teacher Workshops, including Triton College's Cernan Earth and Space Center in Chicago.

Teachers and students learn about the solar system and stars through the use of tactile paper plate maps. Photos courtesy of DePaul University.

EDUCATORS AND SCIENTISTS TEAM UP WITH IDEAS

The Initiative to Develop Education through Astronomy and Space Science (IDEAS) Grant Program funds educational outreach projects that team educators with scientists. IDEAS was developed to enhance educational opportunities for K–14 students and cultivate innovation and creativity using space science as the underlying concept. The program provides opportunities for scientists to translate current astronomy research into education contexts and to stimulate student interest.

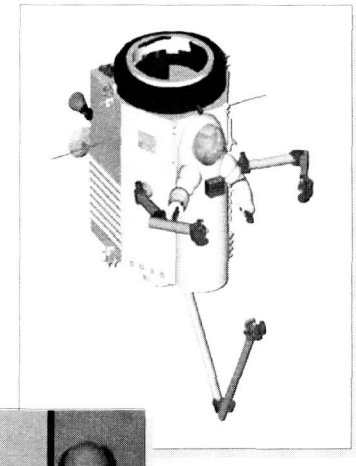
IDEAS, administered by the Space Telescope Science Institute (STScI), is coordinated by the Office of Public Outreach on behalf of NASA. Funding of up to $20,000 is available for small projects up to one year in duration. Larger projects can receive up to $50,000 with a funding period of up to two years. There are no restrictions on the number of proposals that can be submitted. Eligible individuals include scientists currently active in research or educators with at least five consecutive years experience in K–14 or informal science education. The IDEAS Web site (*http://ideas.stsci.edu*) provides a list of other funding sources available (private and corporate). Any questions or comments should be e-mailed to ideas@stsci.edu. The deadline for applying for funds for IDEAS 2003 is October 24, 2003.

SPACE SCIENCE RESEARCHERS NEEDED TO ADOPT A PLANET

Planetary information is coming in at an unprecedented pace. This pace will continue to increase as new information arrives from the fleet of international spacecraft currently moving toward their destinations. Maintaining an accurate Web site is challenging and requires regular monitoring of the content. NASA's Solar System Exploration Web site needs scientists to "adopt" pages that will feature new discoveries. Volunteers are asked to monitor the content of these pages to ensure that they reflect the most current knowledge. Presenting accurate, regularly updated data is the best way to eliminate misconceptions and to educate the public about space science. Interested scientists should visit the Web site at *http://sseforum.jpl.nasa.gov/scientists/index.cfm*.

MARYLAND WINS RASC–AL COMPETITION FOR TOP UNIVERSITY DESIGN

The University of Maryland brought home top honors at the 2003 RASC–AL Design Competition for its innovative efforts in spacewalk hybridization. The Maryland team refers to their plan as the Space Construction and Orbital Utility Transport (SCOUT) concept. Conventional pressure-suit technologies and infrequent spacewalk opportunities on the International Space Station (ISS) led to the development of the SCOUT system. SCOUT represents a hybrid between pressure-suit design and dexterous robotic servicing systems in a self-contained spacecraft. The team's "astronaut-in-a-can" concept would provide a constant shirt-sleeve environment and zero-delay initiation of operations without the need for denitrogenation in an airlock chamber. Based on the student design, a section of the vehicle would incorporate advanced pressure-suit arms for hands-on spacewalk tasks. For more information on the RASC–AL program, visit the Web site at *http://www.lpi.usra.edu/rasc-al/rascal2003/*.



The University of Maryland design team wins the 2003 RASC–AL Design Competition with its concept of a Space Construction and Orbital Utility Transport (SCOUT) system.

NEWS FROM SPACE

METEORITES RAINED ON EARTH AFTER MASSIVE ASTEROID BREAKUP

Using fossil meteorites and ancient limestone unearthed throughout southern Sweden, marine geologists at Rice University in Houston, Texas, have discovered that a colossal collision in the asteroid belt some 500 million years ago led to intense meteorite strikes over the Earth's surface. The research, sponsored by the National Geographic Society and the Swedish Research Council, is based upon an analysis of fossil meteorites and limestone samples from five Swedish quarries located as much as 310 miles (500 kilometers) apart. The limestone formed from sea bottom sediments during a 2-million-year span about 480 million years ago, sealing the intact meteorites, as well as trace minerals from disintegrated meteorites, in a lithographic time capsule.

"What we are doing is astronomy, but instead of looking up at the stars, we are looking down into the Earth," said lead researcher Birger Schmitz, who conducted his analysis during his tenure as the Weiss Visiting Professor of Earth Science at Rice. Schmitz is professor of marine geology at Göteborg University in Sweden. Some 20% of the meteorites landing on Earth today are remnants of a very large asteroid that planetary scientists refer to as the "L-chondrite parent body." This asteroid broke apart around 500 million years ago in what scientists believe is the largest collision that occurred in late solar system history. Schmitz and his colleagues looked for unique extraterrestrial forms of the mineral chromite that are found only in meteorites from the L-chondrite breakup. They found that all the intact fossil meteorites in the Swedish limestone came from the breakup. Moreover, they found matching concentrations of silt and sand-sized grains of extraterrestrial chromite in limestone from all five quarries, indicating that meteorite falls occurred uniformly over the entire area following the breakup.

AMATEUR ASTRONOMERS ENJOY GREAT VIEWS OF MARTIAN DUST CLOUDS

Something is happening on Mars and it's so big you can see it through an ordinary backyard telescope. On July 1, 2003, a bright dust cloud spilled out of Hellas Basin, a giant impact crater on Mars' southern hemisphere. The cloud quickly spread and by July 4 was 1100 miles wide — about one-fourth the diameter of Mars itself. "The cloud can be seen now through a telescope as small as 6 inches," says Donald Parker, executive director of the Association of Lunar and Planetary Observers (ALPO). "A red filter helps," he notes. "Even a piece of red or orange gelatin held between the eye and ocular will improve the visibility of the dust."

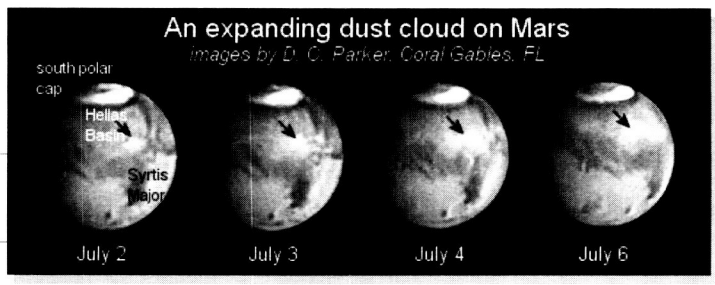
Two years ago, a similar cloud from Hellas Basin grew until it circled the entire planet. Features on Mars long familiar to amateur astronomers — the dark volcanic terrain of Syrtis Major, for example — were hidden for months. "The planet looked like an orange billiard ball," recalls Parker.

Will it happen again? "No one knows," says astronomer James Bell of Cornell University who studied the dust storm of 2001 using the Hubble telescope. "We don't yet understand the mechanism that causes regional clouds to self-assemble into giant dust storms."

All dust storms on Mars, no matter what size, are powered by sunshine. Solar heating warms the martian atmosphere and causes the air to move, lifting dust off the ground. Because the martian atmosphere is thin — about 1% as dense as Earth's at sea level — only the smallest dust grains hang in the air. Mars reaches perihelion — its closest approach to the Sun — on August 30. During the weeks around perihelion, sunlight striking Mars will be 20% more intense than the annual average.

Will dust storms cause problems for those missions currently en route to Mars? Probably not. NASA spacecraft have encountered Mars dust before. The Viking landers of 1976, for instance, weathered two big dust storms without being damaged. In 1971, the Mariner 9 spacecraft reached Mars during the biggest dust storm ever recorded. The planet was completely obscured; not even the polar caps were visible. Mission controllers simply waited a few weeks for the storm to subside.

As 2003 unfolds, Earth and Mars are drawing together for their closest approach in some 60,000 years on August 27. Even the most untrained observer has been able to easily see Mars in the southern sky, a remarkably bright red star.



These pictures of Mars were captured by Donald Parker of Coral Gables, Florida, using a 16-inch telescope. The black arrows indicate the growing cloud.

CALMER SKIES ABOUT SATURN'S ATMOSPHERE

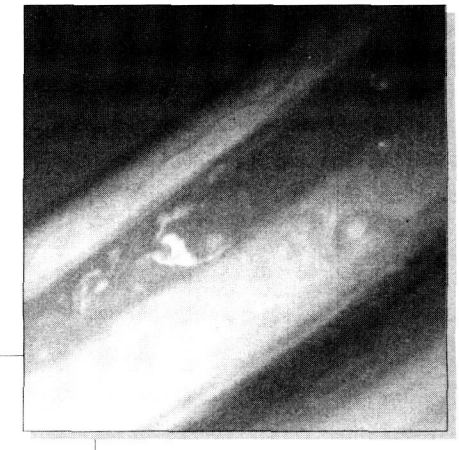
Saturn, one of the windiest planets, has recently had an unexpected and dramatic change in weather: Its equatorial winds have subsided from a rapid 1700 kilometers per hour during the Voyager spacecraft flybys in 1980–1981 to a modest 990 kilometers per hour from 1996 to 2002. This slowdown in the winds has been detected by a Spanish-American team of scientists, including Richard French of Wellesley College in Massachusetts, who reported their findings in the June 5 issue of the journal *Nature*.

Using Hubble Space Telescope (HST) images of the ringed giant planet, the Spanish-American team of scientists (A. Sanchez-Lavega, S. Perez-Hoyos, J. F. Rojas, and R. Hueso from Universidad Pais Vasco in Bilbao, Spain, and French from Wellesley College) measured the

motions of cloud features and storm systems on the ringed giant planet. "One of the major mysteries in atmospheric sciences is why the giant planets Jupiter and Saturn — huge spheres composed mainly of hydrogen and helium — have an alternating pattern of east-west winds, which vary in direction with latitude," explains French. "Unlike winds on terrestrial planets like Earth, which are powered primarily by sunlight, winds on the giant planets have an additional energy source in the heat that escapes from their deep interiors. Even though the strength of this interior heat is a mere fraction of the sunlight on Earth, the giant planets' winds are ten times more intense than terrestrial winds."

The role of these interior energy sources in sustaining these strong winds in giant planets and understanding why the maximum speed is reached at the equator constitute major challenges to theories of atmospheric motion in planets and stars. There currently are two quite different explanations for the system of jets on giant planets. At one extreme, the winds are thought to extend very deep into the interior of the planet, tapping the heat released from the planet to drive their motions. At the other extreme, the atmospheric circulation is modeled as on the terrestrial planets, driven by the solar heat deposited in a shallow upper atmospheric layer. Both explanations have important drawbacks, and neither can account for the strong equatorial winds.

Using the high-resolution capability of the Wide Field Planetary Camera onboard the HST, the Spanish-American team has been able to track enough cloud elements in Saturn to measure the wind velocity over a broad range of latitudes. The equatorial winds measured in 1996–2001 are only half as strong as was found in 1980–1981, when the Voyager spacecraft visited the planet. In contrast, the windy jets far from the equator have remained stable and show a strong hemispheric symmetry not found in Jupiter.



This enhanced color image of the northern hemisphere of Saturn shows a variety of features in Saturn's clouds. Time-lapse images of cloud features like those shown in this image not only provide information on how these storms evolve with time, but provide a way to measure atmospheric wind speeds. Photo courtesy of NASA.

The different behavior of Saturn's winds could have a simple explanation, note the scientists. The long seasonal cycle in Saturn's atmosphere (one Saturn year is about 30 terrestrial years) and the equatorial shadowing by the planet's giant rings could account for the sudden slowdown in the equatorial winds. Rather than being tied to the deep interior of Saturn, driven primarily by internal heat, the equatorial winds could be, in part, a shallow surface phenomenon, affected as well by seasonal variations in sunlight. In fact, Saturn's equatorial region has been the location of giant storm systems, such as those seen in 1990 and 1994. These storms may have induced strong dynamical changes, perhaps resulting in the observed weakening of the equatorial winds.

New HST observations by the Spanish-American team are planned for the end of this year. The new data and the high-resolution imaging to be obtained by the NASA-ESA Cassini orbital mission expected to arrive at Saturn in mid-2004 will enable them and other scientists to learn whether the current wind pattern will persist or will change over the course of Saturn's seasonal cycle. In either case, notes French, "these results will be important tests of our theoretical understanding of winds on the giant planets."

EVIDENCE FOR METEOR IN EARLY MASS EXTINCTION FOUND

Twenty years ago scientists discovered that a small asteroid or comet was involved in the mass extinction at the so-called K-T boundary at which the dinosaurs died out, about 65 million years ago. Louisiana State University geophysicist Brooks Ellwood and four other researchers have just published an article in the journal *Science* in which they tie an even earlier mass extinction to a meteor strike. This extinction happened 380 million years ago in what is called the middle Devonian. It was a time when only small plants, wingless insects, and spiders inhabited the land and everything else lived in the sea. About 40% of all species disappeared from the fossil record at this time. The extinction has been known to geologists for a long time, but this is the first time it has been tied to a meteor strike. This is also the oldest known impact that has been tied to a mass extinction.

Because the extinction and the meteor strike happened at the same time does not prove the impact caused the extinction, but it certainly suggests it. One of the great difficulties in determining whether an extinction happened on a global scale, or was a local event caused by a volcano or some other terrestrial force, is identifying the same strata of rock at different locations on the globe. The layer Elwood was looking at — near the top of a barren plateau in the Anti Atlas desert near Rissani in Morocco — was about the thickness of a felt-tipped marker and only distinguishable from the soil around it by its reddish color. Ellwood was able to find high concentrations of shocked quartz, microscopic spherules, and microcrysts in this layer, sure signs of a meteor impact.

"We know that meteors have struck the Earth hundreds of times," Ellwood said. "If I had to guess, I would say that once every 5 million years a meteor big enough to cause a mass extinction hits the Earth. We could protect ourselves if we wanted. We went to the moon, we can figure out how to destroy or deflect a meteor. All it takes is the political will — and an awareness of the threat."

YOUR NAME COULD MAKE A "DEEP IMPACT" ON A COMET

NASA is launching a campaign to send hundreds of thousands of names to Comet Tempel 1. The names will be carried onboard NASA's Deep Impact spacecraft, the first deep-space mission designed to really reach out and touch a comet. Mission scientists are confident an impact on a comet's nucleus will answer basic questions about the nature and composition of these celestial wanderers.

"This is an opportunity to become part of an extraordinary space mission," said Dr. Donald Yeomans, an astronomer at the Jet Propulsion Laboratory in Pasadena, California, who is a member of Deep Impact's science team. "When the craft is launched in December 2004, yours and the names of your loved ones can hitch along for the ride and be part of what may be the best space fireworks show in history."

The flyby spacecraft will take pictures as a 370-kilogram (816-pound) copper-tipped impactor plunges into Tempel 1 at about 37,000 kilometers (22,990 miles) per hour on July 4, 2005. The impactor is expected to make a spectacular, football field-sized crater, seven to fifteen stories deep, in the speeding comet. Carried onboard the impactor will be a standard mini-CD containing the names of comet, space, and other enthusiasts from around the world.

"This campaign will allow people from around the world to become directly involved with Deep Impact and through that get them thinking about the scientific reasons for the mission," said University of Maryland astronomy professor Michael A'Hearn, Deep Impact's principal investigator. "We particularly hope to capture the interest of young students, as they will become the explorers of the next generation."

People may submit their names for this historic one-way mission by visiting NASA's Deep Impact Web site, from May 2003 to February 2004, at *http://deepimpact.jpl.nasa.gov/*.

GIRL WITH DREAM NAMES MARS ROVERS

Twin robotic geologists NASA is sending to Mars will embody in their newly chosen names — "Spirit" and "Opportunity" — two cherished attributes that guide humans to explore.

NASA Administrator Sean O'Keefe and 9-year-old Sofi Collis, who wrote the winning essay in a naming contest, unveiled the names in June at NASA's Kennedy Space Center. "Now, thanks to Sofi Collis, our third grade explorer-to-be from Scottsdale, Arizona, we have names for the rovers that are extremely worthy of the bold mission they are about to undertake," O'Keefe said.

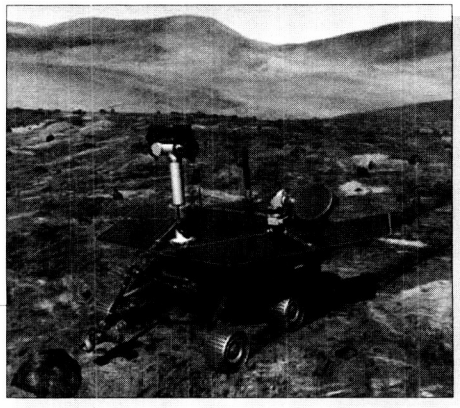
Sofi read her essay: "I used to live in an orphanage. It was dark and cold and lonely. At night, I looked up at the sparkly sky and felt better. I dreamed I could fly there. In America, I can make all my dreams come true. Thank you for the 'Spirit' and the 'Opportunity'."

Collis' essay was selected from nearly 10,000 entries in the contest sponsored by NASA and the Lego Co., a Denmark-based toymaker, with collaboration from the Planetary Society in Pasadena, California. Collis was born in Siberia. At age two, she was adopted by Laurie Collis and brought to the United States. "She has in her heritage and upbringing the soul of two great spacefaring countries," O'Keefe said.

MARS MISSIONS UPDATE

With the launch of Opportunity on July 7, the fleet of new robotic explorers of Mars is now successfully on its way! Opportunity, the second of two American Mars Exploration Rovers, joins three other vessels on their way to the fabled Red Planet. Spirit, the first rover, was launched on June 10, shortly after the European orbiter/lander mission Mars Express/Beagle 2 in May. Nozomi, a Japanese mission to study the upper atmosphere of Mars, is already on its way to an orbit of Mars in early 2004.

Mars Express will be the first to reach its destination. Scheduled for arrival on December 26, the orbiter has several instruments that will map the surface from orbit (*http://www.sci.esa.int/marsexpress/*). Beagle 2 will land in Isidis Planitia, a relatively flat plain in the center of an ancient impact basin near the equator of Mars. It carries several instruments to probe and characterize the soil and will search for evidence of life. The current Mars Exploration Rovers are roughly twice the size of Sojourner, which was flown on the Mars Pathfinder mission and landed on the planet in 1997 (*http://mars.jpl.nasa.gov/MPF/*). Spirit and Opportunity will wander several hundred meters across the surface, mapping the landing site and examining the nature and composition of the rocks. Opportunity is scheduled to arrive on January 4, 2004, at Meridiani Planum, which is composed partly of hematite, a mineral usually precipitated from water. On January 24, 2004, Spirit will land in the center of Gusev Crater, a crater that is believed to have been filled at one time with a large lake more than 100 kilometers (62 miles) wide. The lake is now dry, but the sediment remaining could contain important information on the early climate of Mars.



NASA's twin robot geologists, the Mars Exploration Rovers, are underway in search of answers about the history of water on the Red Planet. The rovers are targeted to sites that appear to have been affected by liquid water in the past, and will drive to various locations to perform onsite scientific investigations over the course of their 90-day missions. Photo courtesy of NASA/JPL.

Opportunities and Notices

Postdoctoral and Visiting Scientist Positions at the Lunar and Planetary Institute (LPI)

The Universities Space Research Association's Lunar and Planetary Institute (LPI) in Houston, Texas, has several available positions in planetary science research at the Postdoctoral and Visiting Scientist levels. Applicants may propose to work in any area of the planetary sciences, with preference given to topics that enhance the interactions between LPI and the Astromaterials Research Group at the NASA Johnson Space Center (JSC).

Applicants for both types of position should have a Ph.D. in planetary sciences or a geosciences-related field. Postdoctoral positions will be offered for an initial period of up to two years, with possible extension to a maximum of three years. Visiting Scientist positions will generally be offered for periods of 1–12 months and are available for scientists with established records of research productivity.

Applicants should send a letter of interest, a curriculum vita with list of relevant publications, a brief (maximum three pages) statement of proposed research, and a list of three references. There is no firm application deadline and applications will be reviewed periodically. Application materials should be sent to

Dr. Stephen Mackwell
Director, Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston TX 77058-1113

Further information on current research and facilities at the LPI can be found at *http://www.lpi.usra.edu*. The Universities Space Research Association is an Equal Opportunity Employer.

Important Notice About Future Issues

Dear Readers,

The *Lunar and Planetary Information Bulletin* is also published in electronic format. Issues are available on the LPI's Web site at

http://www.lpi.usra.edu/lpib/

Issues are published in PDF format, viewable with the Adobe Acrobat Reader (available free of charge from http://www.adobe.com). The electronic version includes full-color versions of many of the exciting images featured in the newsletter, as well as links to the many Web sites mentioned in the articles and a link to previous issues of the *Bulletin*.

As printing costs and budgetary restrictions increase, the cost of continuing to publish the *Bulletin* in hard-copy format becomes a strain on the limited fiscal resources of the LPI. We have therefore reached the difficult decision of **discontinuing the printed version** of the *Bulletin* beginning in 2004 (Issue 97).

Reminder notices will be sent out as each issue becomes available on line. We realize that this may present an inconvenience to some of our readers, and will make every effort to continue to serve our readership as efficiently as possible while working within the budgetary constraints we are faced with. If you do not have Web access, but would like to continue to be able to read the quarterly issues of the *Bulletin*, please contact our staff at lpibed@lpi.usra.edu.

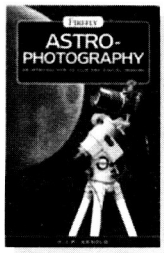
Sincerely,

Editorial Staff, *Lunar and Planetary Information Bulletin*

NEW AND NOTEWORTHY

These products are available from booksellers or the publisher listed. Please note that the LPI does not offer these products through its order department.

BOOKS

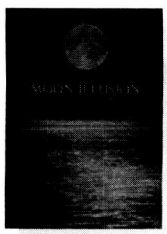


Astrophotography: An Introduction to Film and Digital Imaging. By H. J. P. Arnold. Firefly Books Ltd., 2003. 256 pp. Paperback, $19.95. *www.fireflybooks.com*

In this new edition of the classic introduction to this fascinating hobby, H. J. P. Arnold guides the reader step by step through all aspects of astroimaging — with a camera alone, with a telescope, and with the most up-to-date digital technology. Illustrated with more than 100 color and black-and-white photographs, star charts, and diagrams, Astrophotography is practical and informative. Topics include choosing and using a camera; getting the best quality out of photographic film, CCDs, digital cameras, and photography at the telescope; photographing the Sun, Moon, planets, and stars; processing astrophotographs at home; and special projects.

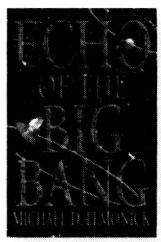
Aquagenesis: The Origin and Evolution of Life in the Sea. By Richard Ellis. Penguin Group USA, 2003. 320 pp., Paperback, $15.00. *www.penguinputnam.com*

For the first hundreds of millions of years, the only living creatures on Earth were underwater. Then, some 350 million years ago, for reasons unknown, a primitive vertebrate crawled out of the water — and stayed out. Richard Ellis, one of America's foremost authorities on ocean life, takes on the deep mysteries of evolution in the sea, tracing its path from the first microbes to the jawless, finless creatures that evolved into the myriad species alive today, including sharks, whales, seals, penguins, dolphins . . . and humans.



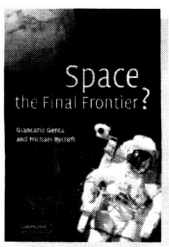
The Mystery of the Moon Illusion: Exploring Size Perception. By Helen E. Ross and Cornelis Plug. Oxford University Press, 2002. 250 pp., Hardback, $45.00. *www.oup-usa.org*

For thousands of years, one scientific puzzle has fascinated and perplexed the greatest philosophers, mathematicians, physicists, and psychologists: Why do the Moon and Sun appear so much larger on the horizon than when high up in the sky? Exploring the theories from antiquity to now, this book examines the mystery that has fascinated and tested the greatest minds throughout the ages.



Echo of the Big Bang. By Michael D. Lemonick. Princeton University Press, 2003. 232 pp., Hardcover, $24.95. *pup.princeton.edu*

Launched in 2001, the Wilkinson Microwave Anisotropy Probe (WMAP) has finally reported in from the cold of deep space a million miles from Earth and has revealed things nobody ever expected. On February 11, 2003, the team of researchers went public with the results. A few of their extraordinary findings: The universe is 13.7 billion years old. The first stars "turned on" when the universe was only 200 million years old, five times earlier than anyone had thought. Author Michael Lemonick, who had exclusive access to the researchers as WMAP gathered its data, tells the full story of WMAP and its surprising revelations.



Space, the Final Frontier? By Giancarlo Genta and Michael Rycroft. Cambridge University Press, 2003. 430 pp., Hardcover, $29.00. *www.cup.org*

What future possibilities for space travel are the most likely to succeed? What are the greatest challenges and advantages of space travel for humankind? What are the potential moral and ethical implications of our space explorations? This book illustrates the possibilities that the exploration and subsequent exploitation of space opens up for humankind. Authors Giancarlo Genta and Michael Rycroft delve into the factors that encourage space travel and speculate on the future of human expansion into space, including the value and importance of having humans in space; the human exploration and colonization of our solar system; robotic exploration of the outer planets, their satellites, and asteroids; the future possibility that humans may leave our solar system; the prospects and implications of our meeting other intelligent beings in space; and the likelihood, consequences, and benefits of future space technologies.

VIDEOS

Project Gemini DVD. Produced by Mark Gray. Spacecraft Films, 2003. Three-disc set, total running time over five hours, $49.99. *www.spacecraftfilms.com*

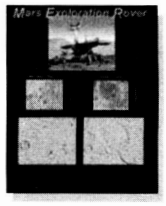
This visual history of Project Gemini includes all the onboard Gemini motion picture footage and unique footage of the development of the Gemini spacecraft and Titan II launch vehicle. Get a unique glimpse into the cockpit as a suited crewmember tests his ability to reach and view each control in the spacecraft. See stacking operations of a Gemini-Titan and multi-angle coverage of every Gemini launch. This three-disc set presents a comprehensive look at this complex project that provided the seasoning in men and machines that led to success in Apollo.

JOURNALS

Planetary Science Research — PSRD. Online journal. *www.psrd.hawaii.edu*

This online journal for space science information and education features in-depth articles on meteorites, planets, and other solar system bodies based on published research. Articles include the motivation behind the research, how the new results are inspiring fundamental discoveries about our solar system, and ongoing debates. The Web site is supported by the Cosmochemistry Program of the NASA Office of Space Science and the Hawai'i Space Grant Consortium. It includes news, references, and links to supplemental resources including free email announcements of new issues, glossary, search tools, classroom activities, and space missions. Authors are encouraged to submit articles written for a general audience following the online submission guidelines.

POSTERS



Mars Exploration Rover Poster. Available on line from the University of Arizona Lunar and Planetary Laboratory Space Imagery Center, 2003. *www.lpl.arizona.edu/SIC/*

In images and text, this poster describes the mission of the Mars Exploration Rovers, including launch windows, arrival dates, descriptions of the selected landing sites, and scientific instruments and goals. A large file (151 MB) for a 26" × 32.5" poster is available to download and print at www.lpl.arizona.edu/SIC/MER (file name MER.tif).

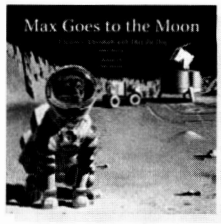
Environmental Effects of Impact Cratering Poster. Designed by Jake Bailey, Maria Schuchardt, Nisha Babu, and David A. Kring. University of Arizona Lunar and Planetary Laboratory Space Imagery Center, 2002. $5.50. *www.lpl.arizona.edu/SIC/*

This colorful 23" × 29" poster shows local, regional, and global environmental effects of impact cratering, including atmospheric heating, tsunamis, shock waves, and global wildfires.

NEW FOR KIDS

Books

Max Goes to the Moon: A Science Adventure with Max the Dog. By Jeffrey Bennett. Big Kid Science, 2003. 32 pp., Hardback, $16.95. *www.bigkidscience.com*



Max Goes to The Moon tells the story of how Max the dog and a young girl named Tori undertake a quest to make the first trip to the Moon since the Apollo era. Their trip inspires the people back on Earth to join together to build a great Moon colony, complete with a university and an astronomical observatory. The colony helps inspire everyone with a message of unlimited human potential and the importance of respecting our home planet. Everything that happens in the story actually has some related behind-the-scenes science, and "Big Kid Boxes," which appear along the sides of the pages, offer simple explanations of key science concepts. The book concludes with a simple activity that parents and children can try together.

Videos

Astronauts and Other Exciting Careers in Space. Produced by Edward W. Flanagan. Manitou Motion Picture Company, Ltd., 2001. VHS, total running time 30 minutes, digitally mastered, $13.45. *www.manitoupix.com*

What does it take to be an astronaut or forge any career in the space program? Strap yourself in and feel the excitement of launch preparations, the exhilaration of sitting atop a controlled explosion that hurls you into orbit, and the wonder of walking in space! The sky is NO limit in this educational adventure from Manitou Motion Pictures. Filmed on location at the Kennedy and Johnson Space Centers (and in orbit!), this film gives young people a look at what it's really like to be an astronaut, as well as to pursue other intriguing careers in space. Produced with the cooperation of NASA, the Johnson and Kennedy Space Centers, Boeing, Lockheed Martin, the United States Space Foundation, and the Astronauts' Hall of Fame.

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	C-RSPECTG	ALTA REFLECTANCE SPECTROMETER CLASSROOM LESSONS **(CD-ROM)**		$5.00	
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OTHER PUBLICATIONS

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CALENDAR 2003

Information was valid as of this issue's publication and is subject to change without notice. For more information see the Web sites listed.

August

3–8 **Instruments, Methods, and Missions for Astrobiology VI (AM115),** San Diego, California. *http://www.spie.org/conferences/Programs/01/am/confs/4495.html*

5–7 **Third International Conference on Large Meteorite Impacts,** Nördlingen, Germany. *http://www.lpi.usra.edu/meetings/largeimpacts2003*

10–15 **Workshop on Cometary Dust in Astrophysics,** Crystal Mountain, Washington. *http://www.lpi.usra.edu/meetings/stardust2003*

11–16 **The Fourth G. Gamow's Odessa Astronomical Summer School,** Odessa, Ukraine. *http://www.odessa2000.cjb.net*

14–17 **International Mars Society Conference 2003,** Eugene, Oregon. *http://www.marssociety.org/*

14–17 **International Air & Space Symposium and Exposition,** Dayton, Ohio. *http://www.aiaa.org*

17–24 **Order and Chaos in Stellar Planetary Systems,** St. Petersburg, Russia. *http://www.astro.spbu.ru/AGAVA/*

September

2–6 **35th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society,** Monterey, California. *http://dps03.arc.nasa.gov*

7–12 **Thirteenth Annual V. M. Goldschmidt Conference,** Kurashiki, Japan. *http://www.ics-inc.co.jp/gold2003*

8–12 **12th UN/ESA Workshop on Basic Space Science,** Beijing, China. *http://www.seas.columbia.edu/~ah297/un-esa/*

8–20 **NATO Advanced Study Institute Program Chaotic Worlds: From Order to Disorder in N-Body Gravitational Dynamic Systems,** Cortina D'Ampezzo, Italy. *http://www.astro.gla.ac.uk/users/martin/nato/cortina03.html*

15–20 **The Sun and Planetary Systems — Paradigms for the Universe,** Freiburg, Germany. *http://www.kis.uni-freiburg.de/AG03/*

18–21 **International Meteor Conference,** Bollmannsruh, Germany. *http://aipsoe.aip.de/~rend/2003imc.html*

22–23 **IAA/ESA — The Next Steps in Exploring Deep Space,** Noordwijk, The Netherlands. *http://www.estec.esa.nl/conferences/03C39/*

23–25 **AIAA SPACE 2003 Conference,** Long Beach, California. *http://www.aiaa.org/space2003/*

24–26 **Fifth IAA International Conference on Low-Cost Planetary Missions,** Noordwijk, The Netherlands. *http://www.estec.esa.nl/conferences/03A04/index.html*

October

4–9 **American Institute of Professional Geologists 40th Annual Meeting,** Glenwood Springs, Colorado. *http://www.aipg.org*

11–12 **The Astronomical Society of the Pacific 115th Annual Meeting,** Berkeley, California. *http://www.astrosociety.org/events/meeting.html*

13–16 **Multiwavelength Mapping of Galaxy Evolution,** Venezia, Italy. *http://www.eso.org/venice03*

13–17 **Third International Conference on Mars Polar Science and Exploration,** Alberta, Canada. *http://www.lpi.usra edu/meetings/polar2003*

November

2–5 **Geological Society of America Fall Meeting,** Seattle, Washington. *http://www.geosociety.org/meetings/2003*

10–14 **30th International Symposium on Remote Sensing of Environment,** Honolulu, Hawaii. *http://isrse.pdc.org/*

16–22 **International Lunar Conference 2003,** Kohala Coast, Hawai'i Island, Hawai'i. *http://www.spaceagepub.com/ilc_2003.html*

17–23 **IAU Colloquium 194 "Compact Binaries in the Galaxy and Beyond,"** La Paz, Mexico. *http://www.astrosen.unam.mx/~iau194/casatest.html*

18–19 **American Astronautical Society National Conference and 50th Annual Meeting,** Houston, Texas. *http://www.astronautical.org/*

December

2–4 **37th ESLAB Symposium: Tools and Technologies for Future Planetary Exploration,** Noordwijk, The Netherlands. *http://astro.estec.esa.nl/Resources/conferences/Eslab37/*

8–12 **American Geophysical Union Fall Meeting,** San Francisco, California. *http://www.agu.org/meetings/fm03/*

January 2004

2–4 **Planetfest '04, Pasadena,** California. *http://www.planetary.org/planetfest04/*

4–8 **203rd Meeting of the American Astronomical Society,** Atlanta, Georgia. *http://www.aas.org/*

5–8 **AIAA Aerospace Sciences 42nd Meeting,** Reno, Nevada. *http://www.aiaa.org/calendar/*

11–15 **Symposium on Space Weather,** Seattle, Washington. *http://www.ametsoc.org/*

15–18 **2004 Hawaii International Conference on Sciences,** Honolulu, Hawaii. *http://www.hicsciences.org/*